DEVELOPING AN EARTH-FIXED VISUAL REFERENCE TO AID STABILITY, READAPTATION, AND EGRESS AFTER A WATER LANDING

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INTRODUCTION

Water landings present the worst possible sensory conditions for crews trying to orient and stabilize themselves immediately after long-duration spaceflight. Of the three sensory feedback systems involved in maintaining stability (i.e., proprioceptive, vestibular, and visual), none will provide reliable orientation information under the current water landing scenarios. The proprioceptive and vestibular systems are affected during spaceflight by disuse and adaptation to microgravity. Vision may not suffer the same degradation, but the visual environment within the enclosed space of a capsule, or interior room of a recovery ship, induces instability during wave motion. In addition to an increased fall risk, sensory re-adaptation is delayed until inputs from the three sensory systems can be synchronized with one another and aligned with Earth's gravity. An Earth-fixed visual reference (EFVR) can be provided to increase crewmember stability and allow for earlier readaptation initiation.

Open water Orion egress testing

GOAL

Identify the optimal features of a visual presentation of gravitational reference cues to improve stability & readaptation.

METHODS

- ❑ Subjects (n=18) stood in a three-sided enclosure with feet spaced 2" apart and with one hand in contact, but with minimal force applied to a waist-high handle.
- ❑ Perturbations:
  - Wave motion created by Orion-derived sum-of-sines equations

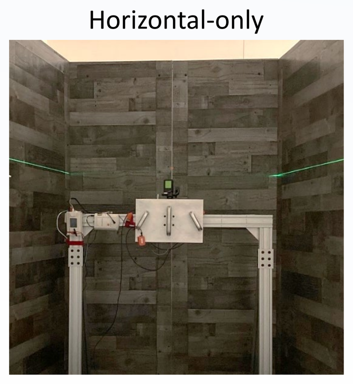
$$Roll = (1.68 \times sin(0.1t - 90)) + (0.84 \times sin(\sqrt{0.05}t - 48)) + (1.04 \times sin(0.361t - 26))$$
$$Pitch = (0.6 \times \sin(0.1t - 90)) + (1.26 \times \sin(\sqrt{0.05}t - 69)) + (0.54 \times \sin(0.361t - 46))$$
$$Heave = (0.78 \times sin(0.1t - 135)) + (0.6 \times sin(\sqrt{0.05}t - 103)) + (0.51 \times sin(0.361t - 86))$$

  - Sum-of-sines galvanic vestibular stimulation (GVS) – max limited to ±3mA

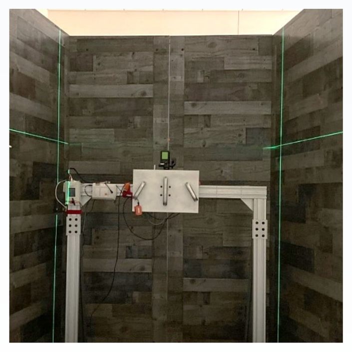
$$GVS_{amplitude} = 300 * (sin(0.16t - 90) + sin(0.32t - 48) + sin(0.43t - 26) + sin(0.61t - 48))$$

  - Standing on foam
- ❑ Conditions (90 second trials)
  - First trial - Control condition with wave-motion only
  - Second & last trial – full perturbation control condition
  - Five visual reference conditions with 2 frontal & 2 peripheral presentation trials counterbalanced around the starfield trial

Peripheral Field Horizontal-only

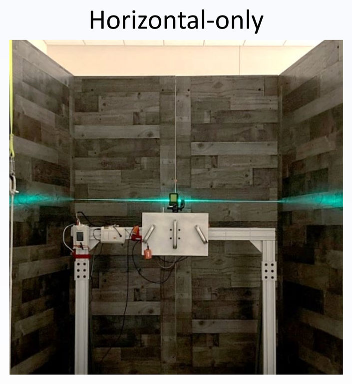


Peripheral Field Horizontal + Vertical

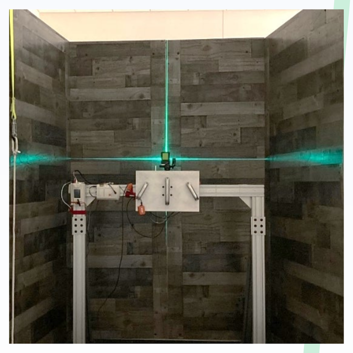


Starfield

Frontal Field Horizontal-only



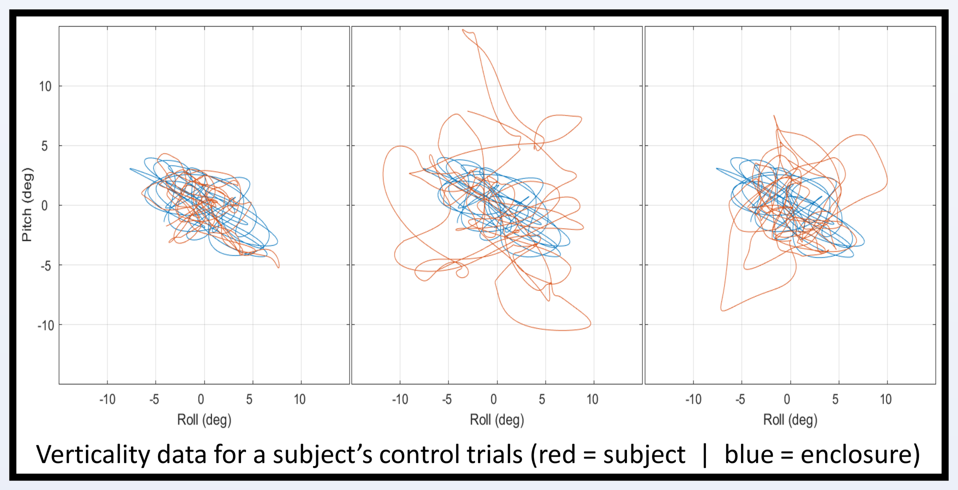
Frontal Field Horizontal + Vertical



Brightness variation and side-wall reflections are a photo artifact & not visible during testing.

RESULTS

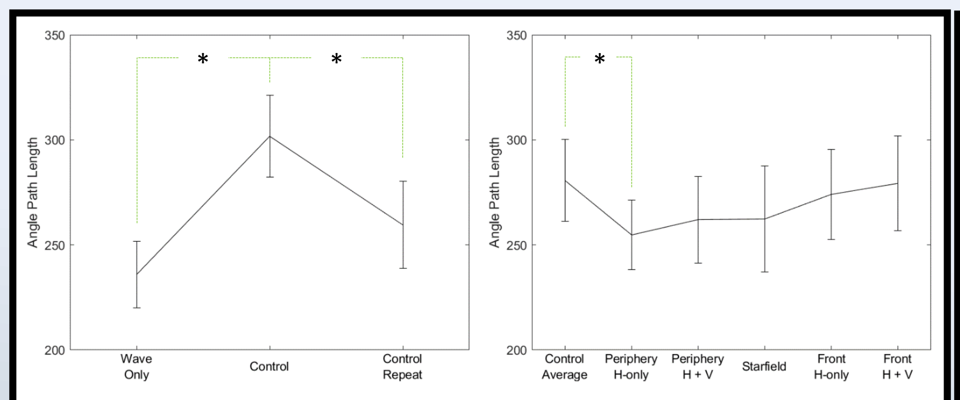
One subject appeared to have misunderstood the instructions, **ALL** others reported that the presence of an EFVR helped them stabilize. Preferences for which presentation is best varied. Peripheral lines were preferred over frontal by 7:4. Five preferred the starfield citing the feedback from their shadow on the front wall, but it was actively disliked by some noting inconsistencies in the periphery.



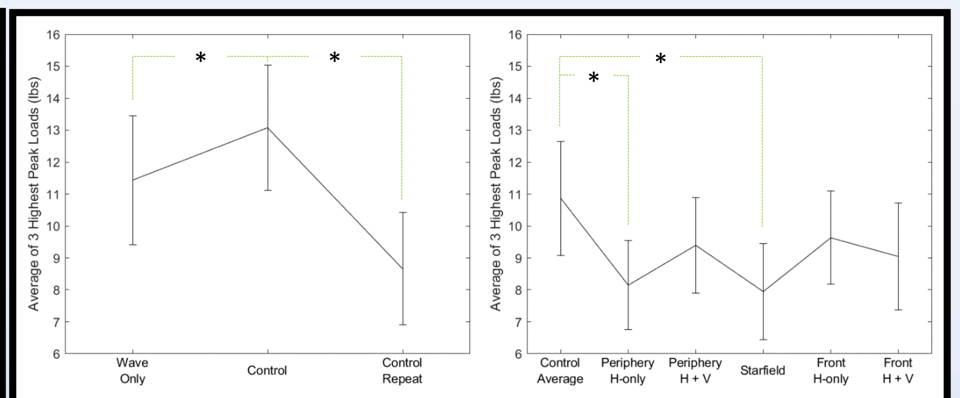
Verticality data for a subject's control trials (red = subject | blue = enclosure)

Stability Data:
- Verticality path length, calculated from IMU pitch & roll data
- Resultant handle forces

Control Results:
- GVS & foam increased instability
- Learning occurred



Verticality path length group means (± standard error)



Average of three highest measured forces group means (± standard error)

A tradeoff between verticality and handle force can complicate the interpretation, but the single peripheral line showed a statistically significant difference in both.

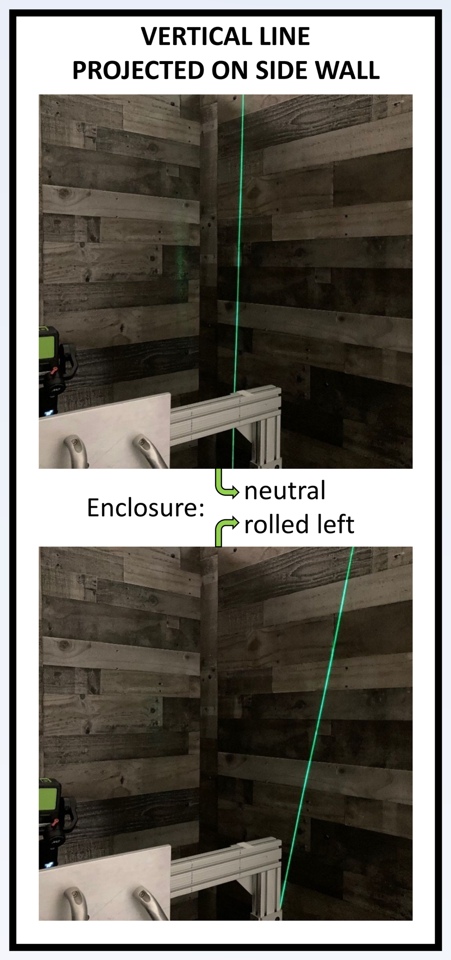
LESSONS LEARNED

Subject observations, that were unrecognizable when standing outside of the enclosure, led to an evaluation of the peripheral projections.

The logical conclusion from the single line in the lower picture is that the enclosure had been pitched forward. It had instead been rolled to the left.

The geometrical relationship between the projected image, the wall, and the axis of rotation can lead to seemingly ambiguous orientation cues.

Starfield proponents focused attention on the feedback provided by their front wall shadow while opponents noticed the ambiguity of the cues in the periphery.



CONCLUSIONS

- ❖ ***ALL** subjects reported that the presence of an earth-fixed visual reference helped them stabilize during simulated water landing sensory conditions.
- ❖ Peripheral presentations were preferred by a majority of the subjects, a result supported in the quantitative outcomes.
- ❖ Future EFVR countermeasure development can address the geometrical relationships concerns and simultaneously provide subject feedback.